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Role of three-dimensional computed tomography venography as a powerful navigator for varicose vein surgery

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Purpose: **Computed tomography venography (CTV) with three-dimensional reconstruction can provide complementary road maps for varicose vein (VV) surgery. The purpose of this study is to verify the role of CTV in the treatment of VV in terms of advantages and complications.**

Methods: **Ninety-four consecutive patients with VV underwent conventional high ligation, stripping, and varicosectomy by a single vascular surgeon in 2007. All patients were evaluated with duplex ultrasound and CTV. Patients with renal dysfunction, allergy to radiocontrast, telangiectasia only, or treated by endovenous laser therapy (EVLT) were excluded from the study. Computed tomography (CT) examination was performed with a 16-Multidetector CT scanner (Siemens, Erlangen, Germany) and 3D images were reconstructed by personal computer-based software (Rapidia, Infinitt, Seoul, Korea). Medical records and the CT images were reviewed retrospectively.**

Results: **VV surgeries were done in 127 limbs of 94 patients (both in 33, right in 29, and left in 32). There were 56 females and 38 males with the mean age of 57 years (range, 28-79 years). The CEAP classification was $C_{2\text{-}3}$ EpAsPr. Perforators larger than 1 mm near the varicose veins were detected and marked on the CT volume-rendering images. The average numbers of perforators marked by CTV were 12.07 ± 4.27 in each limb. The perforators were evaluated by duplex for the presence of reflux (≥0.5 sec). Mean number of perforators with reflux in each limb was 1.41 ± 1.67, which were ligated during the surgery. Incidental detections of other disease were done in six patients, including uterine myomas, an ovarian cyst, a gallstone, a scrotoal varicocele, and a pes anserine bursitis. Operation was performed with the CTV images on screen. CTV was helpful in designing the operation in most patients. Three-D CTV images of saphenopopliteal junction especially provided thorough understanding of the complex variable anatomy of the lesion. There were no CT-related complications, such as renal dysfunction or allergic reaction.**

Conclusions: **CT venography can provide excellent road map for VV surgery without significant complications. It cannot replace duplex ultrasound, but can provide powerful 3D images for designing operation as well as education and research.**
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For the preoperative evaluation of the varicose vein, duplex ultrasound (DUS) is considered the gold standard because of its ability to define the anatomical site of reflux and to quantify the amount of reflux.[1,2] DUS can detect saphenous vein or perforating vein reflux and can be used for preoperative mapping.

Meanwhile, because of recent advances in computed tomography (CT) imaging techniques, multi-detector CT (MDCT) with three-dimensional (3D) reconstruction is available. But there are only a few reports dealing with the role of CTV in varicose vein.[3,4] We applied CT venography (CTV) with 3D reconstruction for the preoperative evaluation of varicose vein. CTV has lots of theoretical advantages. CTV can provide complementary road maps for varicose vein surgery. Visual images provide easy and thorough understanding of the varicose vein anatomy. Anatomical detection of the significant perforators by CTV possibly reduces recurrence due to missed perforators.

We performed a retrospective study to evaluate the feasibility of 3D-CTV in varicose vein surgery in terms of advantages and disadvantages and to define the role of CTV on the evaluation of perforators.

METHODS

CT venography. CT exam was performed with a 16-MDCT (Sensation 16; Siemens Medical Solutions, Erlangen, Germany) scanner. A bolus of 2 mL/kg (maximum 150 mL) of nonionic contrast agent (iopromide, Ultravist 370; Bayer Schering Pharma, Berlin-Wedding, Germany) was injected with a power injector (Envision CT; Medrad Inc, Warrendale, Penn) at a rate of 2.5 mL/s via antecubital vein. The scan delay time was set to three minutes after initiating injection of the contrast agent to enhance deep and superficial veins, including varicose veins and perforating veins. The scan range was from the iliac crest to the end of the feet. The scanning parameters for

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CTV were as follows: detector collimation, 0.75 x 16 mm; pitch, 1.5; slice thickness, 1 mm; reconstruction interval, 0.7 mm; x-ray tube voltage, 100 kVp; effective tube current, 150 mAs.

3D reconstruction. All thin-section axial images were transferred to a workstation running PC-based 3D reconstruction software (Rapidia, Infinitt, Seoul, Korea). Individual volume data were loaded into the 3D program, and one experienced radiologist (WL) performed the 3D reconstruction. The techniques used for 3D reconstruction of the superficial venous system were smoothing of axial images for noise reduction and interactive volume rendering. For the perforator survey, interactively rotating volume-rendered images and corresponding axial, sagittal, and coronal images were used.

Patient selection. Ninety-four consecutive patients with VVs were performed conventional high ligation, stripping, and varicosectomy by a single vascular surgeon (SJK.) in 2007 at Seoul National University Hospital. All patients were evaluated preoperatively with DUS and CTV. Patients with renal dysfunction (serum creatinine >1.5 mg/dl), allergy to radiocontrast, telangiectasia only, or treated by endovenous laser therapy were excluded from the study. Routine protocol for varicose vein operation in our hospital was applied. After patient interview and careful physical examination, preoperative workup with DUS and CTV was done, mostly on the same day. CTV was done first and any veins that perforated the fascia (perforators) larger than 1 mm were detected and marked on the CT volume-rendering images. Presence of reflux in the marked perforators was evaluated by duplex. Retrograde flow more than 0.5 sec was considered as presence of perforator reflux. 3D-CTV images were displayed on the screen during the surgery to provide a roadmap. Routine high ligation and stripping was done and perforators larger than 1 mm with reflux near the varicose veins were ligated.

RESULTS

Patient demographics. A total of 127 limbs of 94 patients were treated. There were 56 females and 38 males. Mean age was 57 years, ranging from 28 to 79 years. CEAP classifications were C 2-3 Ep As Pr in all patients. Median duration of symptoms was seven years (range, 1-30 years). Varicose veins were present on both legs in 33 (35%) patients, right leg in 29 (31%), and left leg in 32 (34%). Locations of the duplex-proven reflux were listed in the Table.

Disadvantages of CTV. Possible disadvantages related to CT, such as renal dysfunction or allergic reaction, were not developed in this series. Radiation exposure and additional cost can be other disadvantages. For the images, CTV cannot provide real-time images like duplex, so the valve movement cannot be evaluated by CTV. But CTV can demonstrate any abnormalities larger than 1 mm in the venous wall, such as wall thickening, intraluminal webs, or acute and chronic thrombosis.

CTV as a navigator for surgery. Excellent 3D-CTV images could be obtained in all patients with the prescribed protocol. The varicose vein anatomy could be demonstrated in 360° angles. And the images could be adjusted to many levels of depth, from skin to deep subcutaneous level (Fig 1). The whole distribution of the varicosity was easily understandable, and the perforators were marked on the enlarged images. Actually, preoperative marking on the patient was not necessary in most cases because CTV images could provide a powerful roadmap during the surgery.

Table. Distribution of varicose veins and reflux

Location	*Right*	*Left*	*Both*
Symptomatic VV	29 (31%)	32 (34%)	33 (35%)
Duplex-proven reflux			
GSV	22	20	27
SSV	5	8	2
GSV + SSV	1	4	4
Perforator only	1	0	0

GSV, Great saphenous vein; *SSV,* small saphenous vein; *VV,* varicose vein.

CTV for the evaluation of the perforators. Any veins that perforated the fascia (perforators) were carefully searched and marked with the 3D reconstruction software (Fig 2). To search important perforators, various sectional images in axial, coronal, and sagittal planes were evaluated. Mean number of perforators larger than 1 mm was 12.07 ± 4.27 in total 188 limbs, 12.06 ± 4.20 in right legs, and 11.32 ± 4.34 in left legs. Mean number of perforators larger than 1 mm with reflux confirmed by duplex were 1.41 ± 1.67 in each limb, which were ligated during the operation. There is little chance of omitting any significant perforators because any veins perforating the fascia can be detected easily by the volume-rendering images. And the images could show the relation of varicosity with the perforators in the same plane, distinguishing major contributing perforators to the varicose cluster (Fig 3).

Revealing unusual anatomic variation. CTV provided comprehensive evaluation of the vascular systems of pelvis and low extremities. Unusual anatomic variations related with varicosity such as a Giacomini vein reflux, accessory GSV reflux, GSV duplication were easily detected. Unusual vascular diseases unrelated with varicosity were detected in six patients; a chronic deep vein thrombosis in popliteal vein, pelvic congestions, iliac vein compressions, and a vascular malformation. For an example, the exact course of the Giacomini vein with reflux in relation with the GSV and SSV can be demonstrated in Fig 4. In a patient with both GSV and SSV insufficiency, CT venography could reveal the main cause of calf varicosity (Fig 5). The patient presented GSV reflux (peak velocity 8.38 cm/s; duration 4880 ms) and SSV reflux (peak velocity 28.37 cm/s; duration 4830 ms) on duplex ultrasound. The CTV images showed the enlarged SSV and small GSV, which meant the main cause of the calf varicosity was SSV reflux, which extended through the varicose vein to mid-calf GSV. High ligation and stripping of the SSV was done, reserving GSV.

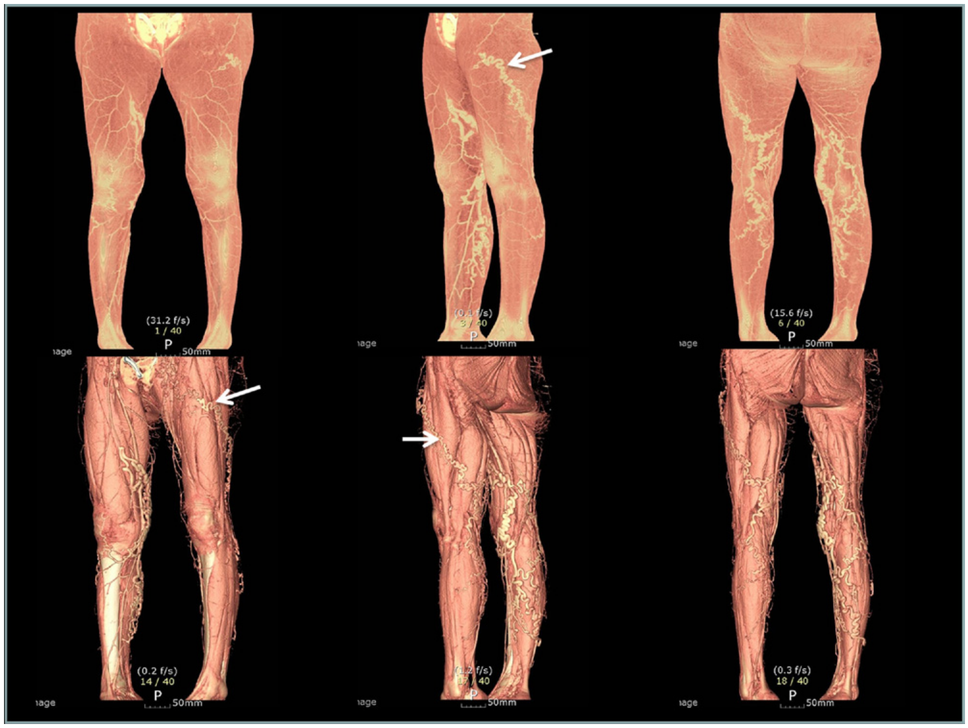

Fig 1. CT venography images as a navigator for surgery. The distribution of the varicosities could be seen in skin level and subcutaneous level. Duplex ultrasound exam confirmed the reflux in both GSV and left anterior accessory GSV extending to the posterior thigh (*arrow*).

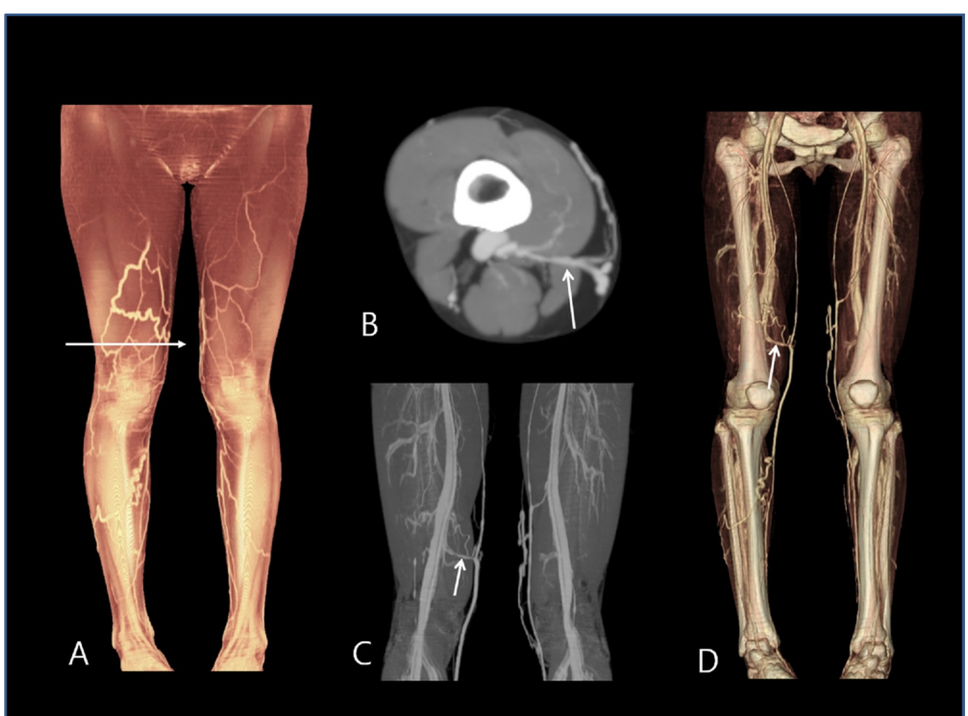

Fig 2. CT venography images of perforator evaluation. **A**, 3D volume-rendering images of the superficial varicosity. The arrow indicates the plane of axial tomography of figure **B**, which shows a perforator of the femoral canal connecting femoral vein and GSV. **C**, This coronal view shows the connection of femoral vein and GSV via a perforator of the femoral canal in the same plane. **D**, Reconstructed 3D image shows the perforators of the femoral canal in both thighs.

Fig 3. CT venography images for the perforator evaluation. Perforators were marked on the 3D-volume rendering images in the same plane with the varicosities. Perforators with reflux were confirmed by duplex ultrasound (*white circle*).

Fig 4. CT venography images in a patient with left Giacomini vein reflux. Duplex sonography confirmed the left GSV and Giacomini vein reflux.

Fig 5. CT venography images in a patient with duplex-proven reflux in left GSV and SSV. The enlarged SSV (*arrow head*) and small GSV (*arrow*) in the upper calf revealed the main cause of the calf varicosity was SSV reflux, extending through the varicose vein to the mid-calf GSV.

The complex anatomy in the popliteal fossa was also evaluated with CTV (Fig 6). These images were informative in understanding the reflux flow to form the varicosity and perform high ligation of sapheno-popliteal junction without complications.

Incidental detection of other combined disease. Unexpected other combined diseases out of vascular system were detected in six patients; uterine myomas in two, an ovarian cyst, a scrotal varicocele, a GB stone, and a pes anserine bursitis in the calf. In a patient with bursitis, CTV explained the leg pain unrelated to varicose vein, and helped the decision to delay varicose vein surgery until the conservative treatment of the bursitis for a few weeks. Two patients with uterine myomas were referred to gynecology and performed operation later.

Easy education tool for patients and students. After the preoperative imaging studies, we usually showed the CTV volume-rendering images to the patients to show the disease extent and method of operation. Most of the patients easily understood the procedures with the 3D images, which was almost impossible with the duplex images. This was also very informative in the education of medical students and surgical residents.

Outcomes. There was no recurrence of varicose vein in all patients during 12 month follow-up periods. Three patients complained of localized hypoesthesia in inner lower calf after GSV stripping, which resolved in six months with conservative management.

DISCUSSION

For the preoperative evaluation of varicose vein, duplex ultrasound is considered as a primary choice because it can provide both anatomical and functional assessment of the venous system in the lower extremities.[5,6] It provides B-mode images of the superficial veins and discriminates the presence and extent of venous reflux with a high sensitivity and specificity.[7] In contrast, identification of perforating vein with duplex ultrasound is more difficult and less accurate. When the number of perforators identified by duplex ultrasound is compared with phlebography, the sensitivity is as low as 79%.[8] Missed perforators with reflux during preoperative evaluation can be a major cause of recurrence after surgical treatment for varicose veins. Duplex ultrasound has many limitations such as operator-dependent variable results, a time-consuming procedure, possible omission of perforators in unusual locations, and a difficulty in the evaluation of pelvic vessels.

In contrary, CT is an objective, non-operator-dependent diagnostic modality. With a CT scan performed within several minutes, we can evaluate pelvic veins as well as lower extremity veins, and arterial disease as well as venous disease at the same time. There are only a few reports dealing with the application of recent CT technology in varicose vein. We tried to apply MDCT technique to get proper images for preoperative varicose vein evaluation, which showed satisfying results.[9]

Fig 6. CT venography images of popliteal fossa with a complex anatomy. **A**, 3D image of varicose vein in the right popliteal area. **B**, Varicose vein in subcutaneous level. **C**, Tortuous varicosity from small saphenous vein reflux. **D**, This magnified image shows that small saphenous vein terminates into the popliteal vein in two separate locations (*arrows*). The reflux flow from the upper saphenopopliteal junction goes up to intersaphenous vein and down to the varicosity.

Possible advantages of CTV in varicose vein surgery are enormous, as listed above. A powerful navigator or roadmap for surgery with no need for preoperative mapping, thorough evaluation of the perforators, revealing unusual anatomic variation, detection of other combined disease, differential diagnosis of deep vein disease, vascular malformation, pelvic congestion syndrome, or vulvar varix. These findings are not always detectable by DUS. CTV is also helpful in the understanding of varicose vein due to unusual causes and in the evaluation of recurrent varicose vein. It can be used as an easy education tool for patients and students and also a research tool for varicose vein anatomy. For the technical point of view, in patients with edema and skin ulceration, it is not easy to get proper images by duplex, but CTV images are not affected by those local factors.

We usually perform DUS after CTV. After performing the CT scan, all thin-section axial images were use to make the 3D reconstruction. The reconstruction could be done by expert technicians, supervised by one experience radiologist (WL), within 15-20 minutes. Whole course of the axial superficial veins were traced in the same plane, and the perforating vein were traced and marked on the 3D images. Then duplex ultrasound was performed. After the evaluation of the axial vein reflux, perforators detected by the CTV were examined to define the presence of reflux. With the CTV, the duplex examiner knows the overview of the varicosity, so knows exactly where to focus to detect any reflux. This might shorten the duration of duplex exam without missing important perforators (personal opinion). In larger vascular centers, DUS is usually performed by registered vascular technicians, and the communication with the vascular surgeon is not always perfect. CTV images can provide objective visual data, minimizing the chance of making a mistake during the varicose vein surgery.

Possible disadvantages of CTV such as renal dysfunction and allergic reaction can be avoided by careful patient selection, as in our series. Radiation exposure can be a problem.[10] Estimated radiation exposures in many procedures are reported as 5 to 21 mSV for cardio intervention, 12 mSv for lower limb stenting, and 10.5 to 27 mSv for endovascular aneurysm repair. For the CTV, it is only 1.6 to 3.9 mSv, which seems to be in an acceptable range.[11,12] Additional cost of CTV can be a disadvantage. But in selected subgroups of patients, such as those with pelvic reflux or unusual anatomic variation, CTV can be beneficial. Another important disadvantage of CTV is that it can provide only anatomical information but not flow dynamics. At this moment, CTV cannot replace duplex, because valvular reflux can be determined only by DUS. But a recent report from our group showed the promising correlation of CTV images with DUS findings.[13]

In brief, the morphologic findings of the insufficient GSVs with varicosity were focal ectasia, diffuse dilatation of more than 6 mm, asymmetry, tortuosity, and direct connection to varicosity. The sensitivity and specificity of CTV for predicting GSV insufficiency were 98.2% and 83.3%, respectively. The sensitivity and specificity of CTV for predicting SSV insufficiency were 53.3% and 94.9%, respectively.[13]

Regarding the possible complications, routine use of CTV for varicose vein workup may not be justified. But in selected groups of patients with pelvic reflux or abdominal or pelvic pathology, recurrent varicosity, or complex anatomy, CTV could be considered as a primary evaluation tool.

The impact of CTV in reducing VV recurrence is an important issue to be answered. Poor surgical technique and neovascularization were the most common reasons accounting for most cases of recurrent varices after surgery (REVAS).[14,15] Perrin et al[16] reported technical or tactical failure for REVAS was 29%, and discussed that perforator veins could be easily missed on preoperative assessment. In this series, two cases of REVAS initially treated in other hospitals were included. One patient had received only ambulatory phlebectomy for calf varicosity eight years ago. We found GSV reflux and performed high ligation and stripping. We suspected GSV reflux had been omitted at the initial workup. The other patient had received GSV high ligation and stripping after duplex exam six months ago in other hospital. He complained of recurrent calf varicosity and swelling. DUS and CTV revealed SSV reflux with a calf perforator insufficiency, which were corrected by high ligation and perforator ligation.

CTV can provide thorough evaluation of perforators and complex anatomy of the varicosity. Theoretically, it can reduce recurrence due to missed perforators or technical failure due to complex variant anatomy. Long-term follow-up data on this matter need to be studied.

CONCLUSION

Three-dimensional CT venography can provide an excellent roadmap for varicose vein surgery without significant complications. 3D CTV cannot replace duplex ultrasound currently, but can provide powerful 3D images for designing operation as well as education and research.

AUTHOR CONTRIBUTIONS

Conception and design: SM, SJK
Analysis and interpretation: SM, SYK, YJP
Data collection: SM, SYK, YJP, WL
Writing the article: SM
Critical revision of the article: WL, IJ, TL, JH, SJK
Final approval of the article: SM, SYK, YJP, WL, IJ, TL, JH, SJK
Statistical analysis: SM, YP
Obtained funding: N/A
Overall responsibility: SJK

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